Interactive Adaptive Interface Using Recursive Fuzzy Reasoning

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Abstract - In the process we design the machine which adapts to the user considering personal difference, this paper consider the interactive relationship that both user and the machine try to adapt each other. We call this relationship as the Interactive Adaptation. The Interactive Adaptive Interface(IAI/F) is the intelligent interface which is designed under consideration of the Interactive Adaptation. This interface changes characteristics of the system according to the given task considering the state of the user such as skill level, technique, characteristics, physical condition etc.. We propose a design and realization method of the IAI/F which is based on the recursive fuzzy reasoning. As an application example, we present a virtual reality simulation game and apply the IAI/F based on the user's performance and the skin potential reflex(G.S.R.). We present the system considering the Interactive Adaptation and show some experimental results and statical evaluation results to discuss its effectiveness.

1. Introduction

In designing an intelligent interface/1-4/, it is important to design the assistance system acts useful. Then, personal difference of the user becomes the problem. For this problem, an adaptive interface which adapts to the user rather than the user adapts to the system has been studied/5-8/. The adaptive interface has the adaptation mechanism so that the system supports the user. CAI(Computer Aided Instruction)/3/ has adaptive assistance capability in the knowledge level. However, in the motion level, it is scarcely reported about the adaptive assistance system considering personal difference. Especially, most of the conventional interfaces in the motion level, such as an semi-automatic operation system, consider only about efficiency for working aim, and displeasure of the user is neglected. So we have studied an interface which is comfortable and efficient for the users in the cooperative work with the machine. We have considered to include the adaptive mechanism based on the G.S.R.(Galvanic Skin Reflex)/9/ which is considered to have the relationship with the uncomfortableness of human, and have shown the effectiveness of this system/8/.

In the previous research work, we have considered the way of the system adapting human. But in reality, human and the machine both try to adapt each other. So, in this paper, we make the interaction between human and the machine important, and we propose a design and realization method of the interactive adaptive interface which is based on the recursive fuzzy reasoning/10/. We present the system considering the interactive adaptation and show statical evaluation results of the experiments to discuss its effectiveness.

2. Interactive Adaptive Interface

In the process that the machine adapts to the user considering interaction between them, we can't neglect relationship that both user and the machine try to adapt each other. We call this relationship as **Interactive Adaptation**. The **Interactive Adaptive Interface(IAI/F)** is an adaptive interface which is designed under consideration of Interactive Adaptation. The Interactive Adaptive Interface changes characteristics of the system according to the given task considering the state of the user such as skill level, technique, characteristics, physical condition. This concept is shown in Fig.1.

In this paper, we aim at realization of the interactive adaptive assistance in the motion level, and propose a design method of an intelligent interface. As a concrete example of the corporatively

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operating system, we applyed this system to the virtual reality simulation game(Air Hockey Game). For various subjects, we have conducted many experiments and statistical evaluation.

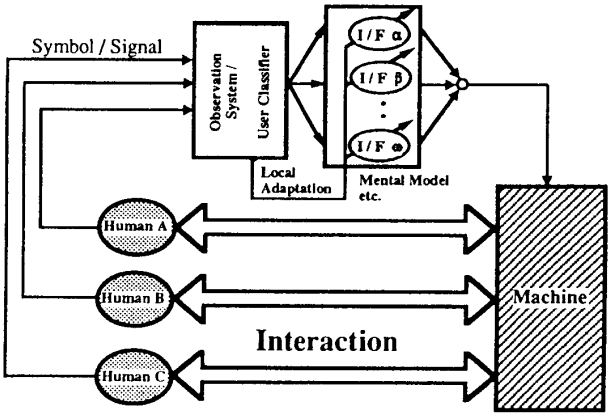


Fig.1 Concept of Interactive Adaptive Interface

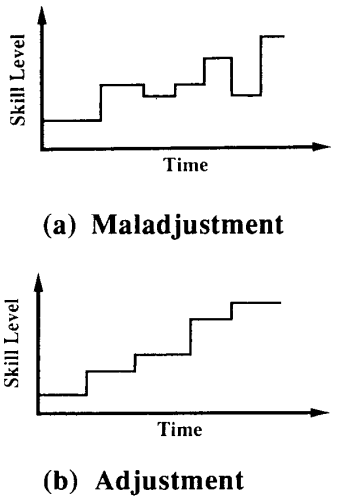


Fig.2 Concept of historical change in adaptation process

3. System Configuration

3.1 Basic System Structure

In realizing an adaptive interface, it is thought that 4 pieces of following knowledges are needed/5/. They are:

1) knowledge of the system;
2) knowledge of the user;
3) knowledge of the application;
4) knowledge of interaction(the system and the user).

Based on these knowledge, the system needs to decide an assistance method or level in adaptive manner corresponding to the user and his condition. Minimum necessary things as the composition elements are (1) **user observation system**, (2) **knowledge data base**, (3) **adaptive assistance system**. The observation system evaluates the task performance of the user and measure the mental stress. If the mental stress is high, the interface is changed so as to reduce the mental stress and to improve the performance. To use psychological parameter to design the assistance system is scarcely performed before.

3.2 Evaluation Method of Operational State

The skill level of the user can be judged by evaluating the task performance objectively. On the other hand, psychological measurement of the user has been studied actively in the experimental psychological field. Recently it became possible to measure relatively easily an electro-encephalo-gram, an electrocardiogram, a heartbeat, respiration, skin potential reflex, eye movements, and so on. Moreover, research works concerning human recognition processing which is based on these measurement analyses have been studied so far. But, it is difficult to understand the condition of the user completely, because the data quantity is too much for individual difference and they are complicated. So, in this paper, in order to do simplification

at a problem as much as possible, we pay attention to the evaluation result of the task performance and mental stress of the user, and propose the way how to change the assistance system adaptively. Here, we use the Galvanic Skin Reflex to evaluate the psychological state of the user. A G.S.R. measuring apparatus is used in the experiments frequently for the several psychological experiments.

3.3 Assistance Method

The assistance method at the adaptive assistance part is divided into the knowledge level and the motion level. In this paper, we consider the Interactive Adaptation in the motion level. The system change the automation level according to the user's performance and the mental state.

In designing the intelligent interface, it is important to make the useful assistance system. In general, if the skill level of the user is low, it is preferable to make the strong assistance system. On the other hand, for the user whose skill level is high, the strong assistance system may make the task boring, and the opportunity to exercise will decrease. So, in this paper, as the skill level of the user becomes high, we make the system reduce the automation level.

On the other hand, when the mental stress is increased, we increase the assistance level to improve the performance. If the performance is improved, the mental stress may decrease and the working condition will be improved. This will be good effect for the user performing the task. This is a kind of interactive effect caused by rising the assistance level.

3.4 Interactive Adaptive Assistance Using Recursive Fuzzy Reasoning

In the case that the users skill is only evaluated by the indirect parameter such as score, it is possible that sudden change of the assistance system caused by some unpredictable matter will occur depend on the sampling period. In such cases, assistance level changes suddenly in the previous system/8/. Generally speaking, few people can adapt such sudden change and it is not preferable for the user. This will cause maladjustment of the user to the assistance system. The concept of this situation is written in Fig.2(a). That is to say, in the process of the user getting used to the system, the followings are the problems to realize Interactive Adaptation.

(1) It is difficult to get the characteristics of the user continuously.
(2) It is difficult to adjust from the single observation.
(3) The user can't cope with the sudden change of the system.

So, as the method to prevent sudden change and to consider the interaction of both human and the machine try to adapt each other, we propose the method to decide the assistance level under the historical change of the measurement data. Moreover, change of human is obvious in general, fuzzy reasoning is preferable to decide the assistance level. So, considering these points, we propose the method of calculating the assistance level using the recursive fuzzy reasoning/10/. Equations (1) and (2) represent the recursive fuzzy reasoning extended form the equations of the simplified fuzzy reasoning.

$$f^{(1)}=\frac{\sum_{i,j}(\mu_{\alpha}^{(1)}\times\mu_{\beta}^{(1)})\,K(\alpha_i^{(1)},\beta_j^{(1)})}{\sum_{i,j}(\mu_{\alpha}^{(1)}\times\mu_{\beta}^{(1)})} \qquad (n=1) \qquad (1)$$

$$f^{(n)}=\frac{\sum_{k=0}^{n}\sum_{i,j}\rho^{k}(\mu_{\alpha}^{(n-k)}\times\mu_{\beta}^{(n-k)})\,K(\alpha_i^{(n-k)},\beta_j^{(n-k)})}{\sum_{k=0}^{n}\sum_{i,j}(\mu_{\alpha}^{(n-k)}\times\mu_{\beta}^{(n-k)})} \qquad (n\geq 2) \qquad (2)$$

Where ρ : Fading factor

In calculating the assistance level, by considering the historical change of the measurement data, we are possible to estimate the user's skill level change roughly. Then the gradual improvement of the skill level written in Fig.2(b) can be attained. This kind of system can keep

pace with the user, and we call it as the " **Pacing System** ". The pacing system changes the assistance level in accordance with the performance and the user's mental state, and it will improve the user's skill gradually. It can be applied for an educational system.

4. Experimental System

Next we present the concrete application example of the system. We used the virtual reality simulation game(Air Hockey Game/8/) as the basic model, because it is relatively easy for realization and for implementation of the assistance system.

In the Air Hockey Game, a ball runs on a coat, and the user strikes back the ball by a racket. Direction and speed of the ball change depend on the contact point at the racket. If the user fails to hit a ball, then a ball disappears, and if the user strikes back, 1 score point is obtained.

An user is covered with a H.M.D.(head mount display), and while seeing a display of the H.M.D., the user play the game. An angle of the user's neck is detected by angle speed sensors of each yaw, roll, and pitch angle directions, and those data are utilized for coordinate transformation of 3D graphics on the display of the H.M.D.. In this way, the user tastes virtual reality world through the H.M.D..

As an input device for locating the racket in the display, a 1 degree of freedom manipulator is used as a joy-stick. An encoder and a DC motor have furnished at the manipulator, and the position control is possible. The experiments are conducted as shown in Fig.3.

Fig.3 Experiment

5. Observation of Psychological State

5.1 G.S.R./9/

It is widely known that the mental stress appears as the change of the G.S.R. in the psychological field. A G.S.R. measuring apparatus can measure the skin potential reflex, which is related to emotion change of a person and is used frequently for psychological experiments. The skin potential reflex of human body is influenced by emotion, especially tension of a person. This apparatus is known widely as a so called lie detector.

With the G.S.R. measuring apparatus, skin potential reflex is detected from resistance value of the middle finger and the third finger of the hand which does not have the joy-stick. Generally, resistance value is constant when a person is in a quiet condition. On the other hand, when a person suffered some stimulation or felt uncomfortableness, resistance value rises. The resistance change reflects the mental state

5.2 Measurement Condition

The G.S.R. measuring apparatus detects a slight change of a skin resistance, so even various influence can be included in the measurement data. For example, if the user talks, or his body is swayed, or the user has a cough, a change appears in the output. In the experiments,

users are prohibited to talk and to do excessive movements, and the experiments are conducted by the condition that there is no other person around the subject. Every people wash their hands with soap before starting the experiments.

5.3 Definition of Mental Stress

Here we define the mental stress in the operational way. Definition of the concept based on the objective operation and the concrete measurement is called operational definition. Here, based on the operational definition, we define the maximum value of the mental stress using the G.S.R..

At first, considering to give the maximum mental stress to the user, we make subjects starts the game without any assistance and without any preparation. We define the maximum value of the G.S.R. as the state of the subject suffering the biggest stress. In the experiments, the maximum value of the G.S.R. is used to normalize the G.S.R. measurement data of each subject.

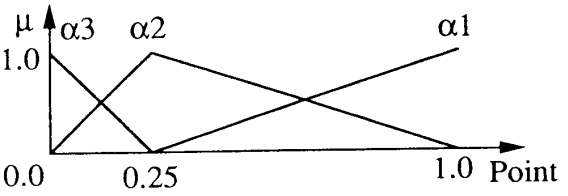
Table 1 Assistance rules

(a)

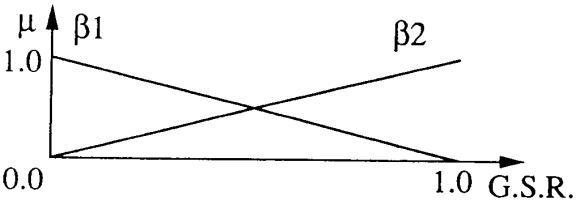
G.S.R. (Mental) / Point (Skill)		Relax	Impatience/ Exitment
		β1	β2
Expert	α1	A1	A2
Middle	α2	A2	A3
Beginner	α3	A3	A4

(b)

Assist	Strength	
No	A1	0.0
Weak	A2	0.33
Middle	A3	0.67
Strong	A4	1.00



(a) Score rate P



(b) G.S.R. ratio

Fig.4 Membership functions

6. Assistance System

One set of the game consists of total 10 sessions. In each session, total ball number is 4 and full score is 15 points. Where, in the first 5 sessions, joy-stick's input moving direction and racket's output moving direction are the same. But in the last 5 sessions, they are set up side down. This is informed to the subjects just before the direction is changed. In the first 5 sessions, the subject gets accustomed to the system to some extent. By this change, we can easily observe how the subject gets accustomed to the task in the following sessions. In the first and the 6th session, assistance system is turned off. In the other sessions, assistance system is turned on and the automatic level is calculated by the recursive fuzzy reasoning.

To calculate the automatic level of the joy-stick, we define the score rate as follows.

Score Rate: P = (Point/15) / (Used Ball Number) x 100 [%] (3)

As an assistance method, we use the compliance control system of controlling deviation between the estimated ball position and the present racket position. The equation of the racket's motion is set as follows.

$$m\ddot{x} = F \quad (4)$$

$$F = k(x_d - x) - c\dot{x} \quad (5)$$

$$k = f^{(n)} \bullet k_0 \quad (6)$$

Where F : Assistance force
k : Assistance force gain

Assistance force is changed by the assistance force gain. k is calculated by the score rate and the G.S.R. ratio using the recursive fuzzy reasoning. Table 1 shows the assistance rule to calculate k. Figure 4 shows the membership functions. Here, the Interactive Adaptation system aims at improvement of the skill level and reduction of the mental stress. Especially, as stated in the chapter 3, we aim at the skill level improvement and don't aim at merely increasing the score rate. So, the assistance force is decreased if the score rate is high. This is because we prevent the system becoming boring and we give opportunity to exercise for the subject. On the other hand, if the mental stress is measured high, we increase the assistance level so that the score rate will rise.

7. Experimental Results

7.1 Evaluation Method

At first, the experiments are conducted for the total number of 29 persons for one set(10 sessions) without the assistance. Next, total number of 14 persons are selected randomly out of those 29 subjects, and they did the experiments to see the effectiveness of using the recursive method. That is, 7 persons selected randomly out of 14 conducted one set with the assistance based on the ordinary fuzzy reasoning first, then they did another one set with the assistance based on the recursive fuzzy reasoning. The other 7 persons out of 14 conducted one set with the recursive method first, next they did another one set with the ordinary fuzzy reasoning. To exclude the effect of the subjects being accustomed to the game from the evaluation based on the criterion function, the order of the experiments are set up side down like this way.

For the evaluation of the experimental results, we used the following criterion function.

$$J = c1 \bullet P + c2 \bullet (1 - G) - c3 \bullet A \quad (7)$$

where

$$G = (G.S.R.)/(G.S.R.max) \quad (8)$$

$$A = k/kmax \quad (9)$$

c1,c2,c3: weight functions

We evaluate the experimental results by setting c1=1, c2=0.5, c3=0.3.

7.2 Analysis of Variance

We conducted the analysis of variance, and the results are shown in Table 2. Table 2 is the results comparing the case of using the recursive fuzzy reasoning with the case of using the ordinary fuzzy reasoning. Variance ratio is 3.671, and this is larger than significant F calculated from F-distribution table(2.909), so the hypothesis " There is difference between the case of using the recursive fuzzy reasoning and the ordinary fuzzy reasoning " is significant at 10% level of significance.

From these results, by using proposed assistance system, we can say that the performance is improved and the G.S.R. is kept low. And realization of the Interactive Adaptation is attained by using the recursive fuzzy reasoning in the system.

Table 2 Effectiveness of Recursive Method

(a) Total Number of subject : 14 persons

Mean of J

F.R.(Fuzzy Reasoning)	2.56
R.F.R.(Recursive Fuzzy Reasoninng)	4.50
Total variable	3.53

(b) Analysis of variance

	Sum of squares	Degree of freedom	Unbiased variance	Variance ratio
Total variation	50.9125	27		
Between class variation	6.29852	1	6.299	3.671
Within class variation	44.6140	26	1.716	

(c) F-distribution

Degree of freedom 1	Degree of freedom 2	Level of significant	F
1	26	0.050	4.225
1	26	0.100	2.909

8. Conclusions

The proposed Interactive Adaptive Interface is effective from the statistical analysis based on the various experiments. The previous problem of sudden change in the assistance level is improved by the recursive fuzzy Inference. In this paper, the assistance rules are fixed for every subjects and we can get fairy good results. But for the realization of much more adaptable interface for a personal use, we hope that the assistance rules can be tuned automatically for each different user in the future. The proposed system can be used for the educational system, and we hope the system is useful for designing the CAI in the motion level.

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